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Description

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Polyurethane PSA for sensitive surfaces

The invention relates to a pressure-sensitive adhesive (PSA) based on a chemically crosslinked polyurethane which attaches well to polar plastics surfaces and smooth metal surfaces and also to glass that shows weak attachment or substantially none at all to paper, paperboard or human skin, which in particular is easily removable without damaging the surfaces during its detachment, and without leaving residues or spots with a greasy appearance, which, additionally, can be used more than once, can be removed by washing and is stable to light, and relates to a reactive coating process for its solvent-free and water-free, continuous preparation, and also relates to the use of the PSA for producing self-adhesive articles, such as adhesive tapes, strips, sheets or pads, for example.

25 Pressure-sensitive adhesion properties or intrinsic adhesion properties are not typical of polyurethanes. Although polyurethanes occupy position five in the list of plastics, in terms of the amounts produced, PSAs of this material play only a very minor role economically.

Nevertheless, polyurethane PSAs have been known for a long time and are described
30 diversely.

The effect of pressure-sensitive adhesiveness can be obtained by adding tackifier resins and/or plasticizers to the polyurethane base polymer. This method is described in, for example, US 3,437,622 A (Dahl et al., Continental Tapes), US 3,718,712 A (Tushaus et

al., 3M), US 4,087,392 A (Hartmann et al., BASF), DE 19 04 102 A (Hagenweiler, BASF) and JP 2000 256 639 (Toyo).

- 5 PSAs of this kind generally have the drawback of not attaching selectively only to certain surfaces. Moreover, following a prolonged period of bonding, they unite – usually strongly – with the surfaces and therefore often cannot be removed.

This “uniting” with the surface is often described by a person skilled in the art as “peel increase”, to describe the increase in bond strength during storage of the adhesive bond.

- 10 It is also possible for the tackifier resin to migrate into the bonded surfaces, where it leaves behind spots which have a greasy appearance.

High peel increase on numerous surfaces, the resultant difficulty of redetachment, and the tendency to leave behind spots with a greasy appearance on many surfaces, are
15 observed not least for those PSAs where the pressure-sensitive adhesiveness is obtained by undercrosslinking: i.e. an amount of isocyanate groups in deficit to the isocyanate-reactive groups, such as hydroxyl or amino groups, for example.

- PSAs designed on the principle of undercrosslinking are described for example in
US 5,157,101 A (Orr, Norwood), DE 24 35 218 A (Adsley et al., Adhesive Tapes),
20 JP 59 227 922 (Sanyo), US 3,930,102 A (Szonn et al., Beiersdorf), US 5,714,543 A (Kydonieus et al., Bristol Myers Squibb), EP 0 597 636 A1 (Kydonieus et al., Squibb) and US 5,591,820 A (Kydonieus et al., Squibb).

- Polyurethane PSAs containing monools fall into a very similar category with analogous
25 weaknesses. Polyurethanes of this kind are likewise undercrosslinked and therefore contain relatively large fractions of migratable polyurethane units of low molecular weight. Polyurethane PSAs on this basis are known for example from EP 0 882 749 A1 (Ikeda et al., Nitto), US 5,227,409 A (Mobley et al., Dow) and US 5,102,714 A (Mobley et al., Dow).

- 30 Another type of polyurethane PSAs uses polyol components which carry hydroxyl groups and contain double bonds. Polyurethane PSAs on this basis are set out for example in JP 02 003 476 (Tsubota et al., Shinko), WO 98/30648 A1 (Gerard et al., Shell), JP 59 230 076 (Sekisui), JP 2001 146 577 (Toyo), US 3,879,248 A (Kest), US 3,743,616 A (Kest), US 3,743,617 A (Kest), US 5,486,570 A (St. Clair, Shell) and US 3,515,773 A
35 (Dahl et al., Continental Tapes). A drawback is the oxidative sensibility of these PSAs,

caused by the double bonds in the polymer main chain. After a certain time this leads to filming or to "blunting" of the pressure-sensitively adhesive surface. In addition the majority of PSAs of this type additionally contain resins, with the disadvantages already described earlier on above.

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A special polyurethane PSA containing carbon-carbon double bonds and based on castor oil, a natural product, is described in US 3,246,049 A (Webber, Norton). Here again the oxidative sensitivity is to be regarded as a weakness.

- 10 EP 0 979 835 A (Questel et al., Elf Atochem) proposes hydroxyl-terminated polyalkylenes as a polyol component, which will solve the problem of oxidative sensitivity. The compositions, however, are moisture-curing, consequently obtain a high ultimate cohesive strength and cannot be used more than once, so that they are unsuitable for reversible adhesive bonding of paper. Furthermore they contain tackifier resins and
- 15 plasticizers, whose disadvantages have already been described earlier on above.

Moisture-curing polyurethane PSAs are also described in, for example, US 4,661,542 A (USM), JP 63 189 486 (Sanyo) and EP 0 196 749 A1 (von Voithenberg et al., Emhart).

- 20 A polyurethane PSA based on hydrogenated polybutadienes is described in JP 01 156 386 (Uehara et al., Hitachi). A drawback there is the need for electron beam crosslinking, which involves a considerable level of technical complexity.

- A polyurethane PSA likewise requiring electron beam curing is known from
- 25 JP 63 260 977 (Uehara et al., Hitachi). It uses polyethers as a polyol component.

- Certain publications describe polyurethane-including blends or polyurethane copolymers having pressure-sensitive adhesive properties. Examples include US 5,910,536 A (Kydonieus et al., Bristol Myers Squibb), US 5,714,543 A (Shah et al., Bristol Myers
- 30 Squibb) and US 4,626,475 A (Barnett et al., Ashland Oil). These PSAs generally feature a heightened tack and are therefore difficult to remove from sensitive substrates without damaging them. As a general rule their pressure-sensitive adhesiveness is not limited selectively to particular surfaces.

Polyurethane PSAs having special additional properties, such as flame retardancy or electrical conductivity, for example, are described in, for example, EP 1 108 768 A1 (Wong, Tyco) or US 4,855,077 A (Hata et al., Takiron).

5 Foamed polyurethanes having pressure-sensitive adhesive properties are likewise known. An example that may be mentioned is the publication DE 24 35 217 A (Adsley et al., Adhesive Tapes), and also the descriptions of hydrophilic foams in DE 42 33 289 A (Kenndoff et al., Beiersdorf) and WO 94/07935 A (Kenndoff et al., Beiersdorf).

10 In principle, as a result of the enlargement of surface area, foamed polyurethanes have the drawback of a heightened oxidative sensitivity and also of a heightened light sensitivity. In practice it has been found that they exhibit strong peel increase on the majority of surfaces and either cannot be removed without damage or else, particularly in the case of the foams made hydrophilic by additions of superabsorbent, interact with the substrate in such a way that spotting occurs.

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Polyurethanes having pressure-sensitive adhesive properties can also be obtained, as demonstrated in JP 2000 073 040 (Toyo) and JP 2000 256 638 (Toyo), by using not only polyethers but also polyesters and also two different catalysts within a polyol component formula. A particular drawback in this case is the increased preparation complexity

20 resulting from the formulas.

JP 2000 328 034 (Toyo), US 3,761,307 A (Dahl) and US 3,925,283 A (Dahl, Continental Tapes) describe pressure-sensitive adhesive polyurethane/-ureas which are obtained by incorporating additional amine-type chain extenders or crosslinkers into the polymer.

25 Drawbacks perceived are the complexity in preparation and the assumed low selectivity of the pressure-sensitive adhesiveness on different surfaces.

DE 21 39 640 A (Dollhausen et al., Bayer) describes a PSA based on an aromatic diisocyanatourethane. A particular drawback is the yellowing tendency, which is typical of

30 aromatic polyurethanes.

In order to achieve pressure-sensitive adhesion properties DE 100 30 908 A (Bolte et al., Henkel) and EP 0 081 103 A1 (Miyake et al., Takeda) proposed using two different isocyanates within a polyurethane composition. In these cases too the complexity in

preparation is found to be a drawback, as is the low selectivity of the pressure-sensitive adhesiveness on different surfaces.

5 WO 97/22642 A1 (Chang et al., Bristol Myers Squibb) proposes, for the preparation of a PSA, heating an NCO-terminated prepolymer and a polyhydroxy compound together at a certain temperature until a gel fraction of 30 to 40% is obtained. A disadvantage of this method is the assumed low selectivity of the pressure-sensitiveness on different surfaces, which results from the relatively low gel content.

10 US 3,796,678 A (Bartizal, 3M) discloses a polyurethane PSA based on capped isocyanate prepolymers which relies on water or organic solvents for its preparation. The complex nature of the preparation is regarded as a drawback, along with the unavoidable need to use water or solvents.

15 A polyurethane latex PSA is described in WO 98/31760 A1 (Schrock et al., Dow Chemical). A drawback is the need for drying, which makes it either impossible or at least very time-consuming to obtain blister-free, relatively thick PSA films.

Certain publications define a polyurethane PSA by way of the crosslinking density.
 20 GB 1,113,925 A (Weller) and GB 1,216,672 A (Grindley) propose chain lengths of 130-285 chain atoms and, respectively, more than 285 chain atoms between the crosslinking points. In practice it has been found that controlling the PSA properties by way of the criterion of chain length alone is an impossibility. An insufficient crosslinking density results in severe peel increase on the majority of substrates after a prolonged
 25 bonding period, while too high a crosslinking density leads to PSAs whose pressure-sensitive adhesiveness is inadequate. Surface-specific selectivity of the PSA properties is not attained.

EP 1 088 871 A1 (Heguri et al., Sekisui) prescribes a certain distance between the
 30 isocyanate groups, or a certain degree of crosslinking, for the polyisocyanate used. The molecular weight between two isocyanate groups in the polyisocyanate is intended to amount to from 220 to 570. This way of controlling the crosslinking density by way of the chain length within the polyisocyanate is likewise unlikely to improve the surface-specific selectivity of the PSA properties.

In US 6,040,028 A (Cline et al., Bayer) as well a polyurethane adhesive (contact adhesive) is defined by way of the molecular weight between crosslinking points. A molecular weight of between 7000 and 16000 is prescribed. Further restrictions are imposed, to the effect, inter alia, that from 0 to 10% of the polyols must have a molecular weight of from 60 to 400 and from 90 to 100% of the polyols must have a molecular weight of from 1800 to 12000.

Here again it must be assumed that the PSA properties are not selectively surface-specific and that on the majority of substrates there will be a sharp peel increase following prolonged adhesive bonding, since the crosslinking density is relatively low and no indications of a possible solution to the problem are given.

WO 01/62818 A1 (Hansen et al., 3M) proposes reacting two polyols or other NCO-reactive materials with isocyanates for the preparation of a polyurethane PSA, the isocyanate-reactive components differing from one another in that one has a molecular weight of more than 2000 and one has a molecular weight of less than 2000.

PSAs of this kind are known inter alia from the examples in US 5,227,409 A and US 3,437,622 A, which also includes the restriction (Claim 5) whereby the isocyanate-reactive components are almost exclusively diols. Additionally, polyurethanes with such a composition have already been described in the examples in EP 1 095 993 A1 and EP 1 101 803 A1, the last-mentioned examples not relating to compositions intended for the obtainment of PSAs. The proposed reaction product in WO 01/62818 A1 is therefore not definitively a PSA. There are no references to a surface-specific selectivity of the PSA properties.

It is an object of the invention to provide a pressure-sensitive adhesive which adheres well to polar plastics surfaces and smooth metal surfaces and also to glass, which in particular is easy to remove, without damaging surfaces during its detachment, particularly when the surfaces are sensitive to mechanical influences, and which does not display the above-described drawbacks of the prior art, or not to the same extent. In particular it should show substantially no adhesion or only very little adhesion to paper, paperboard or similar materials and also to human skin, should essentially not feel tacky, should not leave any residues or spots of greasy appearance following its removal, and should also be able to be used more than once, removed by washing and stable to light.

This object is achieved by means of a polyurethane-based pressure-sensitive adhesive as specified in the main claim. The dependent claims provide advantageous developments of the pressure-sensitive adhesive, processes for its preparation and possibilities for its use.

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The invention accordingly provides a pressure-sensitive adhesive based on polyurethane wherein the polyurethane is composed of the following starting materials which are reacted catalytically with one another in the stated proportions:

- 10 a) at least one aliphatic or alicyclic polyisocyanate having a functionality of in each case less than or equal to three,
 - b) a combination of at least one polypropylene glycol diol and at least one polypropylene glycol triol,
- the ratio of the number of hydroxyl groups in the diol component to the number of
- 15 hydroxyl groups in the triol component being less than 10, preferably between 0.2 and 5,
- additionally the ratio of the number of isocyanate groups to the total number of hydroxyl groups being between 0.8 and 1.15, preferably between 0.95 and 1.05, more preferably between 1.0 and 1.05,
- 20 the catalyst for the reaction to the polyurethane consisting of or comprising a bismuth carboxylate or bismuth carboxylate derivative, and
- the diols and triols alternatively being selected and combined in each case as follows:
- diols having a molecular weight of less than or equal to 1000 are combined
 - 25 with triols whose molecular weight is greater than or equal to 1000, preferably greater than or equal to 3000,
 - diols having a molecular weight of greater than 1000 are combined with triols whose molecular weight is less than 1000.

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In order to produce polyurethanes having sufficient light stability it is necessary, as is known, to use aliphatic or alicyclic polyisocyanates or polyisocyanates containing isocyanate groups which are not aromatically attached. Surprisingly it has been found that aliphatic or alicyclic polyisocyanates are suitable for producing the other desired

35 properties of the polyurethane PSAs in accordance with the object of the invention. The

surface-specific selectivity of the PSA properties in particular can be adjusted to the use of aliphatic or alicyclic polyisocyanates.

In one advantageous embodiment aliphatic or alicyclic diisocyanates are used.

5 Particularly advantageous is the use of aliphatic or alicyclic diisocyanates having in each case an asymmetrical molecular structure, in which, therefore, the two isocyanate groups each possess a different reactivity. In particular the tendency otherwise typically found with pressure-sensitive adhesive polyurethanes, namely that of leaving spots of greasy appearance on paper or paperboard, is markedly reduced through the use of aliphatic or
10 alicyclic diisocyanates having an asymmetric molecular structure. By an asymmetric molecular structure is meant the absence from the molecule of elements of symmetry (for example mirror planes, axes of symmetry, centres of symmetry); in other words, the impossibility of performing any symmetry operation to produce a molecule congruent with the starting molecule.

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Examples of suitable polyisocyanates in accordance with the invention are butane 1,4-diisocyanate, tetramethoxybutane 1,4-diisocyanate, hexane 1,6-diisocyanate, ethylene diisocyanate, 2,2,4-trimethylhexamethylene diisocyanate, ethylethylene diisocyanate, dicyclohexylmethane diisocyanate, 1,4-diisocyanatocyclohexane, 1,3-
20 diisocyanatocyclohexane, 1,2-diisocyanatocyclohexane, 1,3-diisocyanatocyclopentane, 1,2-diisocyanatocyclopentane, 1,2-diisocyanatocyclobutane, 1-isocyanatomethyl-3-isocyanato-1,5,5-trimethylcyclohexane (isophorone diisocyanate), 1-methyl-2,4-diisocyanato-cyclohexane, 1,6-diisocyanato-2,2,4-trimethylhexane, 1,6-diisocyanato-2,4,4-trimethylhexane, 5-isocyanato-1-(2-isocyanatoethyl-1-yl)-1,3,3-trimethylcyclohexane,
25 5-isocyanato-1-(3-isocyanatoprop-1-yl)-1,3,3-trimethylcyclohexane, 5-isocyanato-1-(4-isocyanatobut-1-yl)-1,3,3-trimethylcyclohexane, 1-isocyanato-2-(3-isocyanatoprop-1-yl)cyclohexane, 1-isocyanato-2-(2-isocyanatoethyl-1-yl)cyclohexane, 2-heptyl-3,4-bis(9-isocyanatononyl)-1-pentylcyclohexane, norbornane diisocyanatomethyl, chlorinated, brominated, sulphur-containing or phosphorus-containing aliphatic or alicyclic
30 diisocyanates, and also derivatives of the diisocyanates listed, especially dimerized or trimerized types.

In one particularly preferred embodiment isophorone diisocyanate is used.

With regard to the substantive and quantitative composition of the starting materials reacted with the polyisocyanate it has surprisingly been found that combinations of at least one polypropylene glycol diol and at least one polypropylene glycol triol are suitable for producing polyurethanes having the desired profile of properties in accordance with the object of the invention, if the ratio of the number of hydroxyl groups in the diol component to the number of hydroxyl groups in the triol component is less than 10, preferably between 0.2 and 5.0, if, additionally, the ratio of the number of isocyanate groups to the total number of hydroxyl groups is between 0.8 and 1.15, preferably between 0.95 and 1.05, more preferably between 1.0 and 1.05, if the catalyst for the reaction to the polyurethane consists of or comprises a bismuth carboxylate or a bismuth carboxylate derivative, and if the diols and triols are alternatively in each case selected and combined as follows:

- diols having a molecular weight of less than or equal to 1000 are combined with triols whose molecular weight is greater than or equal to 1000, preferably greater than or equal to 3000,
- diols having a molecular weight of greater than 1000 are combined with triols whose molecular weight is less than 1000.

As polypropylene glycols it is possible to use all commercially customary polyethers based on propylene oxide and a starter which is difunctional in the case of the diols and trifunctional in the case of the triols. Included here are not only the polypropylene glycols prepared conventionally – that is, generally, using a basic catalyst, such as potassium hydroxide, for example – but also the particularly pure polypropylene glycols prepared by DMC (Double metal cyanide) catalysis, whose preparation is described in, for example, US 5,712,216 A, US 5,693,584 A, WO 99/56874 A1, WO 99/51661 A1, WO 99/59719 A1, WO 99/64152 A1, US 5,952,261 A, WO 99/64493 A1 and WO 99/51657 A1.

A characteristic of the DMC-catalyzed polypropylene glycols is that the “nominal” or theoretical functionality of precisely 2 in the case of the diols or precisely 3 in the case of the triols is also actually achieved approximately.

In the case of the conventionally prepared polypropylene glycols the “true” functionality is always somewhat lower than the theoretical functionality, particularly in the case of polypropylene glycols having a relatively high molecular weight. The reason for this is a secondary reaction of rearrangement of the propylene oxide to form allyl alcohol.

It is also possible to use all polypropylene glycol diols or triols containing copolymerized ethylene oxide, which is the case in many commercially customary polypropylene glycols, in order to obtain an increased reactivity towards isocyanates.

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By varying the ratio of the number of hydroxyl groups in the diol to that in the triol within the stated boundaries it is possible to influence the bond strength and to adjust it in accordance with the application. Surprisingly it has been found that the higher the ratio of the number of diol OH groups to the number of triol OH groups the greater the bond strength.

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The bond strength range which can be set within the stated boundaries is approximately up to 3.0 N/cm, measured on steel in accordance with PSTC-101 (see description of the test methods).

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Surprisingly it has been found that the use of a catalyst or catalyst mixture comprising bismuth carboxylate or a bismuth carboxylate derivative, the use of which catalyst or mixture is known for the acceleration of polyurethane reactions, exerts considerable control over the PSA properties of the polyurethane in a manner such that they achieve a surface-specific selectivity.

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Examples of bismuth carboxylates are bismuth trisdodecanoate, bismuth trisdecanoate, bismuth trisneodecanoate, bismuth trisoctanoate, bismuth trisisooctanoate, bismuth trishexanoate, bismuth trispentanoate, bismuth trisbutanoate, bismuth trispropanoate and bismuth trisacetate.

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In one possible embodiment the polyurethane-based PSA includes further formulating ingredients such as, for example, additional catalysts, ageing inhibitors (antioxidants), light stabilizers such as, for example, UV absorbers, rheological additives, and other auxiliaries and additives.

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In the selection of these substances it should be ensured that they do not have any tendency to migrate to the substrate to be bonded, so that there is no spotting occurring in this way. For the same reason the concentration of these substances, particularly the liquid substances, in the composition as a whole is to be kept as low as possible. The

additional use of plasticizers or tackifier resins should therefore be avoided, without any intention thereby to exclude these substances entirely.

5 In order further to accelerate the reaction between the isocyanate component and the isocyanate-reactive component it is possible in addition to use any of the catalyst known to the person skilled in the art, such as tertiary amines or organotin compounds, for example.

The use of antioxidants, though advantageous, is not mandatory.

10 Suitable antioxidants include for example sterically hindered phenols, hydroquinone derivatives, sterically hindered amines, organic sulphur compounds and organic phosphorus compounds.

Light stabilizers or UV absorbers can also optionally be used.

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Light stabilizers used are those disclosed in Gaechter and Müller, Taschenbuch der Kunststoff-Additive, Munich 1979, in Kirk-Othmer (3.) 23, 615 to 627, in Encycl. Polym. Sci. Technol. 14, 125 to 148 and in Ullmann (4.) 8, 21; 15, 529, 676.

20 Examples of rheological additives are pyrogenic silicas, phyllosilicates (for example bentonites), high molecular mass polyamide powders or castor oil derivative powders.

25 In one preferred embodiment the pressure-sensitive adhesive is prepared continuously in accordance with the process described below:

A vessel A is charged substantially with the premixed polypropylene glycol combination (polyol component) and a vessel B is charged substantially with the isocyanate
30 component, it being possible for the other formulating ingredients to have been mixed into these components beforehand in a standard mixing procedure.

The polyol component and the isocyanate component are conveyed via precision pumps through the mixing head or mixing tube of a multi-component mixing and metering unit, where they are homogeneously mixed and so brought to reaction. The chemically inter-
35 reactive components mixed in this way are applied immediately thereafter to a sheet-like

backing material which is preferably moving at a constant speed. The nature of the backing material depends on the article to be produced. The backing material coated with the reactive polyurethane composition is passed through a heating tunnel in which the polyurethane composition cures to the PSA. The coatweight of the polyurethane composition is freely selectable. It depends on the article to be produced. Finally the coated backing material is wound up in a winding station.

The process described allows solvent-free and water-free operation. Solvent-free and water-free operation is the preferred procedure, but is not mandatory. In order, for example, to obtain particularly low coatweights, the components can be diluted appropriately.

In order to enhance the anchorage of the polyurethane composition on the sheet-like backing materials it is possible to use any known method of surface treatment, such as Corona pretreatment, flaming, gas-phase treatment (fluorination, for example). It is possible to use any known methods of priming, in which case the primer layer can be applied either from solution or dispersion to the backing material or else in an extrusion or coextrusion process.

In order to improve the unwind properties of the wound roll it is possible to precoat the reverse of the sheet-like material with a release coating material or for the reverse to carry a co-extruded or extruded-on release coating.

A polyurethane-based pressure-sensitive adhesive as described above wherein the polyurethane is composed of the following starting materials which are reacted with one another in the stated proportions:

- a) at least one aliphatic or alicyclic polyisocyanate having a functionality of in each case less than or equal to three,
- b) a combination of at least one polypropylene glycol diol and at least one polypropylene glycol triol,
the ratio of the number of hydroxyl groups in the diol component to the number of hydroxyl groups in the triol component being less than 10, preferably between 0.2 and 5.0,

additionally the ratio of the number of isocyanate groups to the total number of hydroxyl groups being between 0.8 and 1.15, preferably between 0.95 and 1.05, more preferably between 1.0 and 1.05,

the catalyst for the reaction to the polyurethane consisting of or comprising a bismuth carboxylate or bismuth carboxylate derivative, and
the diols and triols alternatively being selected and combined in each case as follows:

- diols having a molecular weight of less than or equal to 1000 are combined with triols whose molecular weight is greater than or equal to 1000, preferably greater than or equal to 3000,
- diols having a molecular weight of greater than 1000 are combined with triols whose molecular weight is less than 1000,

exhibits outstanding product properties which even the person skilled in the art could have not foreseen in such a way.

The pressure-sensitive adhesive is suitable for fastening or fixing small articles, for example, having sensitive surfaces of polar plastic, glass or metal in such a way that on the one hand these articles are held securely while on the other hand they can be removed without problems at any time, very substantially without the PSA which is now open, i.e., is no longer covered, causing disruption as a result of a high intrinsic tack and without the surfaces of the articles being damaged, contaminated or destroyed by the operation of adhering and removing. The PSA can be used as part of an overall bonding scheme for the adhesive bonding of articles in magazines, books, letters or to papers in general and after the articles have been detached can remain in the magazines, books, letters or papers in general, since it adheres very weakly if at all to these substrates and consequently there is no subsequent sticking together, or at least no irreversible sticking together, of individual pages in the magazines, books, letters or mutually superposed papers in general. Since the pressure-sensitive adhesive as described above also exhibits substantially no adhesion, or at least only weak adhesion, to human skin as well, there is no unpleasant sensation of stickiness on contact.

Following the detachment operation the PSA does not leave behind any residues or spots of greasy appearance on the articles and does not damage the articles, and in particular

does not do so even when these articles are sensitive to mechanical influences, which is often the case with articles having very smooth surfaces.

The pressure-sensitive adhesive as described above can be used more than once without impairment to its bond strength. If the PSA is stored in the unbonded state in a normal environment for a prolonged period without a protective colouring, it naturally becomes dusty, and its bond strength is reduced as a result. Such a layer of dust can easily be removed again at any time using normal mains water. After drying, the original bond strength is immediately reestablished in full. Even large quantities of dust, sand or powders of all grain sizes can easily be removed again by washing.

By virtue of the fact that the PSA is stable to light, it can also be used for adhesive bonding on articles, materials or substrates which are exposed to light and sun, for example on or behind windowpanes or car windows. In general the PSA is equally suitable for both interior and exterior applications.

The intention of the text below is to illustrate the invention with reference to examples, though without wishing to thereby to restrict it.

The following test methods were used briefly to characterize the specimens produced in accordance with the processes described.

- The test specimens were each produced by coating the initially liquid, reactive polyurethane PSA at a coatweight of 50 g/m² onto a 26 µm polyester film and curing it at 100°C. The measurements were made after an "ageing period" (at room temperature) of one week.
- The bond strength was determined in accordance with PSTC-101 (peel adhesion). In accordance with this method the assembly of PSA layer and polyester film is applied to different substrates (steel, ABS, PS, PVC, PP) and then peeled under defined conditions by means of a tensile testing machine. The peel angle is in each case 180° and the peel speed 300 mm/min. The force required for peeling is the bond strength, which is reported with the units N/cm.

- The tack measurement (measurement of the surface stickiness) was made by the die measurement method in accordance with ASTM D 2979-01 using the texture analyser TA 2 from the company SMS (Stable Micro Systems). In accordance with this method a cylindrical steel die is pressed with defined force and rate up to the sample under analysis and is removed again after a defined time at a defined rate. The test result is the maximum force required for its removal, reported with the units N.

The specific test parameters were as follows:

- cylinder radius: 1 mm \Rightarrow cylinder area: 3.14 mm²
- pressing rate: 0.1 mm/s
- pressing force: 5 N
- pressing time: 0.01 s
- removal rate: 0.6 mm / s

- The testing of light stability was carried out using a so-called sunlight lamp from Osram with the designation ULTRA-VITALUX ®, power output 300 W. The samples were uninterruptedly irradiated open from a distance of 50 cm. The temperature of the location of the samples was in each case approximately 60°C. Assessments were made of the colour change of the PSA and also of the change in bond strength in each case after a period of irradiation of one week and of two weeks. This corresponds approximately in each case to a 10-fold uninterrupted real summer sun exposure in central Europe.

Examples

- Coating in the examples was carried out on a standard laboratory coating unit for continuous coating. The sheet width was 50 cm. The coating slot width was variably adjustable between 0 and 1 cm. The length of the heating tunnel was about 12 m. The temperature in the heating tunnel was divisible into four zones each freely selectable between room temperature and 120°C.
- A standard multi-component mixing and metering unit with a dynamic mixing system was used. The mixing head was designed for two liquid components. The mixing rotor had a variable speed of up to approximately 5000 rpm max. The metering pumps of this unit were gear pumps having an output of approximately 2 l/min max.
- The polyol components were prepared in a standard heatable and evacuable mixing tank. During the mixing operation, which took about two hours in each case, the temperature of the mixture was set at about 70°C and a vacuum was applied in order to degas the components.
- Table 1 lists the base materials used to prepare the polyurethane PSAs, in each case with their trade names and manufacturer. The raw materials cited are all freely available commercially.

Trade name	Chemical basis Average molar mass OH or NCO number	Manufacturer/supplier
Desmophen 1262 BD ®	Polypropylene glycol, Diol (M=430) (4661 mmol OH/kg)	Bayer
Desmophen 1112 BD ®	Polypropylene glycol, Diol (M=1000) (1977 mmol OH/kg)	Bayer
Acclaim 4220 N ®	Polypropylene glycol, Diol, high-purity, prepared by DMC catalysis (M=4000) (500 mmol OH/kg)	Bayer
Desmophen 1380 BT ®	Polypropylene glycol, Triol (M=450) (6774 mmol OH/kg)	Bayer
Desmophen 3061 BT ®	Polypropylene glycol, Triol (M=3000) (1000 mmol OH/kg)	Bayer
Desmophen 5035 BT ®	Polypropylene glycol, Triol (M=4800) (624 mmol OH/kg)	Bayer
Acclaim 6320 N ®	Polypropylene glycol, Triol, high-purity, prepared by DMC catalysis (M=6000) (500 mmol OH/kg)	Bayer
Vestanat IPDI ®	Isophorone diisocyanate (M= 222.3) (8998 mmol NCO/kg)	Degussa-Hüls
Vestanat TMDI ®	2,2,4-Trimethylhexamethylene diisocyanate (M=210.3) (9500 mmol NCO/kg)	Degussa-Hüls

Trade name	Chemical basis	Manufacturer/supplier
Desmodur N 3300 ®	Aliphatic polyisocyanate based on hexamethylene diisocyanate (5143 mmol NCO/kg)	Bayer
Desmodur W ®	Dicyclohexylmethane diisocyanate (M= 262) (7571 mmol NCO/kg)	Bayer
	Bismuth trisneodecanoate CAS No. 34364-26-6	
Mark DBTL ®	Dibutyltin dilaurate	Nordmann, Rassmann
Tinuvin 292 ®	Sterically hindered amine, light stabilizer	Ciba
Tinuvin 400 ®	Triazine derivative, UV stabilizer	Ciba
Aerosil R202 ®	Hydrophobicized pyrogenic silica	Degussa-Hüls

Table 1: Base materials used to prepare the polyurethane PSAs, with trade name and manufacturer

Example 1

The composition of the inventive polyurethane PSA is as follows:

5

NCO/OH ratio: 1.02

Ratio of number of diol OH/number of triol OH: 1.5

	Ingredient	Weight fraction [% by weight]	Number of OH or NCO groups based on the percentage weight fraction
A component	Desmophen 1262 BD ®	12.1	56.3 mmol OH
	Acclaim 6320 N ®	75.1	37.5 mmol OH
	Bismuth trisneodecanoate	0.3	
	Tinuvin 292 ®	0.3	
	Tinuvin 400 ®	0.6	
	Aerosil R202 ®	1.0	
B component	Vestanat IPDI ®	10.6	95.7 mmol NCO

10

The test specimens (50 g/m² polyurethane PSA on 26 µm polyester film; see above) achieved the following bond strengths:

- 0.15 N/cm on steel,
- 0.23 N/cm on ABS,
- 0.36 N/cm on PS,
- 0.41 N/cm on PVC.

15

The tack measurement (on steel) gave a figure of 0.4 N. After two weeks of irradiation with the sunlight lamp there were no changes, either in colour or in bond strength. The adhesion to paper and paperboard was extremely low. The PSA was removable from the substrates simply by shaking. The PSA was stuck into a number of books, newspapers and magazines. Even after a bonding period of six months, the pages bonded in this way

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were readily removable from one another and the PSA could be removed readily without leaving residues or greasy spots and without damaging the papers. The PSA did not stick to the skin. Moreover, the PSA was removable by washing. For the purpose of testing it was sprinkled with fine-grained sand and, in a second test, with fine-grained talc. Both
5 substances were easily removable again under running water. Subsequently the bond strength was at the original level. Repeat usability was tested by adhering the PSA to PVC and removing it again 20 times in succession. Thereafter the bond strength was still at the original level.

Example 2

The composition of the inventive polyurethane PSA is as follows:

5

NCO/OH ratio: 1.02

Ratio of number of diol OH/number of triol OH: 1.5

	Ingredient	Weight fraction [% by weight]	Number of OH or NCO groups based on the percentage weight fraction
A component	Desmophen 1262 BD ®	12.3	57.4 mmol OH
	Acclaim 6320 N ®	76.6	38.3 mmol OH
	Bismuth trisneodecanoate	0.3	
B component	Vestanat IPDI ®	10.8	97.6 mmol NCO

10

The test specimens (50 g/m² polyurethane PSA on 26 µm polyester film; see above) achieved the following bond strengths:

- 0.17 N/cm on steel,
- 0.22 N/cm on ABS, 0.31 N/cm on PS,
- 0.44 N/cm on PVC.

15

The tack measurement (on steel) gave a figure of 0.4 N. After two weeks of irradiation with the sunlight lamp there were no changes, either in colour or in bond strength. After two weeks of irradiation there were no colour changes, but the inherent tack was now distinctly perceptible. The bond strength (on steel) was now 1.6 N/cm.

20

The adhesion to paper and paperboard was extremely low. The PSA was removable from the substrates simply by shaking. The PSA was stuck into a number of books, newspapers and magazines. Even after a bonding period of six months, the pages bonded in this way were readily removable from one another and the PSA could be removed readily without leaving residues or greasy spots and without damaging the

- papers. The PSA did not stick to the skin. Moreover, the PSA was removable by washing. For the purpose of testing it was sprinkled with fine-grained sand and, in a second test, with fine-grained talc. Both substances were easily removable again under running water. Subsequently the bond strength was at the original level. Repeat usability was tested by
- 5 adhering the PSA to PVC and removing it again 20 times in succession. Thereafter the bond strength was still at the original level.

Example 3

The composition of the inventive polyurethane PSA is as follows:

5

NCO/OH ratio: 1.02

Ratio of number of diol OH/number of triol OH: 2.5

	Ingredient	Weight fraction [% by weight]	Number of OH or NCO groups based on the percentage weight fraction
A component	Desmophen 1262 BD ®	17.9	83.3 mmol OH
	Acclaim 6320 N ®	66.7	33.3 mmol OH
	Bismuth trisneodecanoate	0.3	
	Tinuvin 292 ®	0.3	
	Tinuvin 400 ®	0.6	
	Aerosil R202 ®	1.0	
B component	Vestanat IPDI ®	13.2	119.0 mmol NCO

10

The test specimens (50 g/m² polyurethane PSA on 26 µm polyester film; see above) achieved the following bond strengths:

- 0.19 N/cm on steel,
- 0.25 N/cm on ABS,
- 0.47 N/cm on PS,
- 0.53 N/cm on PVC.

15

The tack measurement (on steel) gave a figure of 0.5 N. After two weeks of irradiation with the sunlight lamp there were no changes, either in colour or in bond strength. The adhesion to paper and paperboard was extremely low. The PSA was removable from the substrates simply by shaking. The PSA was stuck into a number of books, newspapers and magazines. Even after a bonding period of six months, the pages bonded in this way

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were readily removable from one another and the PSA could be removed readily without leaving residues or greasy spots and without damaging the papers. The PSA did not stick to the skin. Moreover, the PSA was removable by washing. For the purpose of testing it was sprinkled with fine-grained sand and, in a second test, with fine-grained talc. Both

5 substances were easily removable again under running water. Subsequently the bond strength was at the original level. Repeat usability was tested by adhering the PSA to PVC and removing it again 20 times in succession. Thereafter the bond strength was still at the original level.

Example 4

The composition of the inventive polyurethane PSA is as follows:

5

NCO/OH ratio: 1.02

Ratio of number of diol OH/number of triol OH: 4.0

	Ingredient	Weight fraction [% by weight]	Number of OH or NCO groups based on the percentage weight fraction
A component	Desmophen 1262 BD ®	24.5	114.2 mmol OH
	Acclaim 6320 N ®	57.1	28.6 mmol OH
	Bismuth trisneodecanoate	0.3	
	Tinuvin 292 ®	0.3	
	Tinuvin 400 ®	0.6	
	Aerosil R202 ®	1.0	
B component	Vestanat IPDI ®	16.2	145.6 mmol NCO

10

The test specimens (50 g/m² polyurethane PSA on 26 µm polyester film; see above) achieved the following bond strengths:

- 0.26 N/cm on steel,
- 0.53 N/cm on ABS,
- 0.68 N/cm on PS,
- 0.76 N/cm on PVC.

15

The tack measurement (on steel) gave a figure of 0.7 N. After two weeks of irradiation with the sunlight lamp there were no changes, either in colour or in bond strength. The adhesion to paper and paperboard was extremely low. The PSA was removable from the substrates simply by shaking. The PSA was stuck into a number of books, newspapers and magazines. Even after a bonding period of six months, the pages bonded in this way

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were readily removable from one another and the PSA could be removed readily without leaving residues or greasy spots and without damaging the papers. The PSA did not stick to the skin. Moreover, the PSA was removable by washing. For the purpose of testing it was sprinkled with fine-grained sand and, in a second test, with fine-grained talc. Both substances were easily removable again under running water. Subsequently the bond strength was at the original level. Repeat usability was tested by adhering the PSA to PVC and removing it again 20 times in succession. Thereafter the bond strength was still at the original level.

Example 5

The composition of the inventive polyurethane PSA is as follows:

5

NCO/OH ratio: 1.05

Ratio of number of diol OH/number of triol OH: 10.0

	Ingredient	Weight fraction [% by weight]	Number of OH or NCO groups based on the percentage weight fraction
A component	Desmophen 1262 BD ®	38.6	180.1 mmol OH
	Acclaim 6320 N ®	36.0	18.0 mmol OH
	Bismuth trisneodecanoate	0.3	
	Tinuvin 292 ®	0.3	
	Tinuvin 400 ®	0.6	
	Aerosil R202 ®	1.0	
B component	Vestanat IPDI ®	23.2	208.0 mmol NCO

10

The test specimens (50 g/m² polyurethane PSA on 26 µm polyester film; see above) achieved the following bond strengths:

- 0.53 N/cm on steel,
- 1.13 N/cm on ABS,
- 0.95 N/cm on PS,
- 1.18 N/cm on PVC.

15

The tack measurement (on steel) gave a figure of 1.3 N. After two weeks of irradiation with the sunlight lamp there were no changes, either in colour or in bond strength. The adhesion to paper and paperboard was extremely low. The PSA was removable from the substrates simply by shaking. The PSA was stuck into a number of books, newspapers and magazines. Even after a bonding period of six months, the pages bonded in this way

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were readily removable from one another and the PSA could be removed readily without leaving residues or greasy spots and without damaging the papers. The PSA did not stick to the skin. Moreover, the PSA was removable by washing. For the purpose of testing it was sprinkled with fine-grained sand and, in a second test, with fine-grained talc. Both substances were easily removable again under running water. Subsequently the bond strength was at the original level. Repeat usability was tested by adhering the PSA to PVC and removing it again 20 times in succession. Thereafter the bond strength was still at the original level.

Example 6

The composition of the inventive polyurethane PSA is as follows:

5

NCO/OH ratio: 1.02

Ratio of number of diol OH/number of triol OH: 1.0

	Ingredient	Weight fraction [% by weight]	Number of OH or NCO groups based on the percentage weight fraction
A component	Desmophen 1262 BD ®	10.3	47.8 mmol OH
	Desmophen 5035 BT ®	76.7	47.8 mmol OH
	Bismuth trisneodecanoate	0.3	
	Tinuvin 292 ®	0.3	
	Tinuvin 400 ®	0.6	
	Aerosil R202 ®	1.0	
B component	Vestanat IPDI ®	10.8	97.6 mmol NCO

10

The test specimens (50 g/m² polyurethane PSA on 26 µm polyester film; see above) achieved the following bond strengths:

- 0.13 N/cm on steel,
- 0.22 N/cm on ABS,
- 0.36 N/cm on PS,
- 0.32 N/cm on PVC.

15

The tack measurement (on steel) gave a figure of 0.3 N. After two weeks of irradiation with the sunlight lamp there were no changes, either in colour or in bond strength. The adhesion to paper and paperboard was extremely low. The PSA was removable from the substrates simply by shaking. The PSA was stuck into a number of books, newspapers

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and magazines. Even after a bonding period of six months, the pages bonded in this way were readily removable from one another and the PSA could be removed readily without leaving residues or greasy spots and without damaging the papers. The PSA did not stick to the skin. Moreover, the PSA was removable by washing. For the purpose of testing it was sprinkled with fine-grained sand and, in a second test, with fine-grained talc. Both substances were easily removable again under running water. Subsequently the bond strength was at the original level. Repeat usability was tested by adhering the PSA to PVC and removing it again 20 times in succession. Thereafter the bond strength was still at the original level.

Example 7

The composition of the inventive polyurethane PSA is as follows:

5

NCO/OH ratio: 1.02

Ratio of number of diol OH/number of triol OH: 1.0

	Ingredient	Weight fraction [% by weight]	Number of OH or NCO groups based on the percentage weight fraction
A component	Desmophen 1262 BD ®	10.5	48.8 mmol OH
	Desmophen 5035 BT ®	78.2	48.8 mmol OH
	Bismuth trisneodecanoate	0.3	
B component	Vestanat IPDI ®	11.0	99.5 mmol NCO

10

The test specimens (50 g/m² polyurethane PSA on 26 µm polyester film; see above) achieved the following bond strengths:

- 0.15 N/cm on steel,
- 0.28 N/cm on ABS,
- 0.46 N/cm on PS,
- 0.38 N/cm on PVC.

15

The tack measurement (on steel) gave a figure of 0.3 N. After a week of irradiation with the sunlight lamp there were no changes, either in colour or in bond strength. After two weeks of irradiation there were no colour changes, but the inherent tack was now distinctly perceptible. The bond strength (on steel) was now 1.8 N/cm.

20

The adhesion to paper and paperboard was extremely low. The PSA was removable from the substrates simply by shaking. The PSA was stuck into a number of books, newspapers and magazines. Even after a bonding period of six months, the pages

bonded in this way were readily removable from one another and the PSA could be removed readily without leaving residues or greasy spots and without damaging the papers. The PSA did not stick to the skin. Moreover, the PSA was removable by washing. For the purpose of testing it was sprinkled with fine-grained sand and, in a second test, with fine-grained talc. Both substances were easily removable again under running water. Subsequently the bond strength was at the original level. Repeat usability was tested by adhering the PSA to PVC and removing it again 20 times in succession. Thereafter the bond strength was still at the original level.

- 5
 - 10
- After one week of irradiation with the sunlight lamp there were no changes, either in colour or in bond strength. After two weeks of irradiation there were no changes in colour, but the PSA was markedly softer. The inherent tack had increased. The bond strength was now 7.9 N/cm.

Example 8

The composition of the inventive polyurethane PSA is as follows:

5

NCO/OH ratio: 1.02

Ratio of number of diol OH/number of triol OH: 1.5

	Ingredient	Weight fraction [% by weight]	Number of OH or NCO groups based on the percentage weight fraction
A component	Desmophen 1262 BD ®	14.3	66.5 mmol OH
	Desmophen 5035 BT ®	71.0	44.3 mmol OH
	Bismuth trisneodecanoate	0.3	
	Tinuvin 292 ®	0.3	
	Tinuvin 400 ®	0.6	
	Aerosil R202 ®	1.0	
B component	Vestanat IPDI ®	12.6	113.0 mmol NCO

10

The test specimens (50 g/m² polyurethane PSA on 26 µm polyester film; see above) achieved the following bond strengths:

- 0.21 N/cm on steel,
- 0.34 N/cm on ABS,
- 0.52 N/cm on PS,
- 0.48 N/cm on PVC.

15

The tack measurement (on steel) gave a figure of 0.5 N. After two weeks of irradiation with the sunlight lamp there were no changes, either in colour or in bond strength. The adhesion to paper and paperboard was extremely low. The PSA was removable from the substrates simply by shaking. The PSA was stuck into a number of books, newspapers

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and magazines. Even after a bonding period of six months, the pages bonded in this way were readily removable from one another and the PSA could be removed readily without leaving residues or greasy spots and without damaging the papers. The PSA did not stick to the skin. Moreover, the PSA was removable by washing. For the purpose of testing it was sprinkled with fine-grained sand and, in a second test, with fine-grained talc. Both substances were easily removable again under running water. Subsequently the bond strength was at the original level. Repeat usability was tested by adhering the PSA to PVC and removing it again 20 times in succession. Thereafter the bond strength was still at the original level.

Example 9

The composition of the inventive polyurethane PSA is as follows:

5

NCO/OH ratio: 1.02

Ratio of number of diol OH/number of triol OH: 2.5

	Ingredient	Weight fraction [% by weight]	Number of OH or NCO groups based on the percentage weight fraction
A component	Desmophen 1262 BD ®	20.7	96.4 mmol OH
	Desmophen 5035 BT ®	61.8	38.6 mmol OH
	Bismuth trisneodecanoate	0.3	
	Tinuvin 292 ®	0.3	
	Tinuvin 400 ®	0.6	
	Aerosil R202 ®	1.0	
B component	Vestanat IPDI ®	15.3	137.6 mmol NCO

10

The test specimens (50 g/m² polyurethane PSA on 26 µm polyester film; see above) achieved the following bond strengths:

- 0.31 N/cm on steel,
- 0.62 N/cm on ABS,
- 0.58 N/cm on PS,
- 0.52 N/cm on PVC.

15

The tack measurement (on steel) gave a figure of 0.7 N. After two weeks of irradiation with the sunlight lamp there were no changes, either in colour or in bond strength. The adhesion to paper and paperboard was extremely low. The PSA was removable from the substrates simply by shaking. The PSA was stuck into a number of books, newspapers

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and magazines. Even after a bonding period of six months, the pages bonded in this way were readily removable from one another and the PSA could be removed readily without leaving residues or greasy spots and without damaging the papers. The PSA did not stick to the skin. Moreover, the PSA was removable by washing. For the purpose of testing it was sprinkled with fine-grained sand and, in a second test, with fine-grained talc. Both substances were easily removable again under running water. Subsequently the bond strength was at the original level. Repeat usability was tested by adhering the PSA to PVC and removing it again 20 times in succession. Thereafter the bond strength was still at the original level.

Example 10

The composition of the inventive polyurethane PSA is as follows:

5

NCO/OH ratio: 1.02

Ratio of number of diol OH/number of triol OH: 4.0

	Ingredient	Weight fraction [% by weight]	Number of OH or NCO groups based on the percentage weight fraction
A component	Desmophen 1262 BD ®	27.7	129.3 mmol OH
	Desmophen 5035 BT ®	51.8	32.3 mmol OH
	Bismuth trisneodecanoate	0.3	
	Tinuvin 292 ®	0.3	
	Tinuvin 400 ®	0.6	
	Aerosil R202 ®	1.0	
B component	Vestanat IPDI ®	18.3	164.8 mmol NCO

10

The test specimens (50 g/m² polyurethane PSA on 26 µm polyester film; see above) achieved the following bond strengths:

- 0.42 N/cm on steel,
- 0.81 N/cm on ABS,
- 0.68 N/cm on PS,
- 0.73 N/cm on PVC.

15

The tack measurement (on steel) gave a figure of 1.0 N. After two weeks of irradiation with the sunlight lamp there were no changes, either in colour or in bond strength. The adhesion to paper and paperboard was extremely low. The PSA was removable from the substrates simply by shaking. The PSA was stuck into a number of books, newspapers

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and magazines. Even after a bonding period of six months, the pages bonded in this way were readily removable from one another and the PSA could be removed readily without leaving residues or greasy spots and without damaging the papers. The PSA did not stick to the skin. Moreover, the PSA was removable by washing. For the purpose of testing it was sprinkled with fine-grained sand and, in a second test, with fine-grained talc. Both substances were easily removable again under running water. Subsequently the bond strength was at the original level. Repeat usability was tested by adhering the PSA to PVC and removing it again 20 times in succession. Thereafter the bond strength was still at the original level.

Example 11

The composition of the inventive polyurethane PSA is as follows:

5

NCO/OH ratio: 0.90

Ratio of number of diol OH/number of triol OH: 0.3

	Ingredient	Weight fraction [% by weight]	Number of OH or NCO groups based on the percentage weight fraction
A component	Desmophen 1262 BD ®	5.3	24.6 mmol OH
	Desmophen 3061 BT ®	81.9	81.9 mmol OH
	Bismuth trisneodecanoate	0.3	
	Tinuvin 292 ®	0.3	
	Tinuvin 400 ®	0.6	
	Aerosil R202 ®	1.0	
B component	Vestanat IPDI ®	10.6	95.8 mmol NCO

10

The test specimens (50 g/m² polyurethane PSA on 26 µm polyester film; see above) achieved the following bond strengths:

- 0.41 N/cm on steel,
- 0.43 N/cm on ABS,
- 0.51 N/cm on PS,
- 0.51 N/cm on PVC.

15

The tack measurement (on steel) gave a figure of 0.5 N. After two weeks of irradiation with the sunlight lamp there were no changes, either in colour or in bond strength. The adhesion to paper and paperboard was extremely low. The PSA was removable from the substrates simply by shaking. The PSA was stuck into a number of books, newspapers

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and magazines. Even after a bonding period of six months, the pages bonded in this way were readily removable from one another and the PSA could be removed readily without leaving residues or greasy spots and without damaging the papers. The PSA did not stick to the skin. Moreover, the PSA was removable by washing. For the purpose of testing it was sprinkled with fine-grained sand and, in a second test, with fine-grained talc. Both substances were easily removable again under running water. Subsequently the bond strength was at the original level. Repeat usability was tested by adhering the PSA to PVC and removing it again 20 times in succession. Thereafter the bond strength was still at the original level.

Example 12

The composition of the inventive polyurethane PSA is as follows:

5

NCO/OH ratio: 0.95

Ratio of number of diol OH/number of triol OH: 0.7

	Ingredient	Weight fraction [% by weight]	Number of OH or NCO groups based on the percentage weight fraction
A component	Desmophen 1262 BD ®	11.1	51.5 mmol OH
	Desmophen 3061 BT ®	73.5	73.5 mmol OH
	Bismuth trisneodecanoate	0.3	
	Tinuvin 292 ®	0.3	
	Tinuvin 400 ®	0.6	
	Aerosil R202 ®	1.0	
B component	Vestanat IPDI ®	13.2	118.8 mmol NCO

10

The test specimens (50 g/m² polyurethane PSA on 26 µm polyester film; see above) achieved the following bond strengths:

- 0.63 N/cm on steel,
- 0.51 N/cm on ABS,
- 15 • 0.49 N/cm on PS,
- 0.52 N/cm on PVC.

The tack measurement (on steel) gave a figure of 0.5 N. After two weeks of irradiation with the sunlight lamp there were no changes, either in colour or in bond strength. The adhesion to paper and paperboard was extremely low. The PSA was removable from the
20 substrates simply by shaking. The PSA was stuck into a number of books, newspapers

and magazines. Even after a bonding period of six months, the pages bonded in this way were readily removable from one another and the PSA could be removed readily without leaving residues or greasy spots and without damaging the papers. The PSA did not stick to the skin. Moreover, the PSA was removable by washing. For the purpose of testing it was sprinkled with fine-grained sand and, in a second test, with fine-grained talc. Both substances were easily removable again under running water. Subsequently the bond strength was at the original level. Repeat usability was tested by adhering the PSA to PVC and removing it again 20 times in succession. Thereafter the bond strength was still at the original level.

Example 13

The composition of the inventive polyurethane PSA is as follows:

5

NCO/OH ratio: 0.95

Ratio of number of diol OH/number of triol OH: 1.5

	Ingredient	Weight fraction [% by weight]	Number of OH or NCO groups based on the percentage weight fraction
A component	Desmophen 1262 BD ®	19.9	92.5 mmol OH
	Desmophen 3061 BT ®	61.7	61.7 mmol OH
	Bismuth trisneodecanoate	0.3	
	Tinuvin 292 ®	0.3	
	Tinuvin 400 ®	0.6	
	Aerosil R202 ®	1.0	
B component	Vestanat IPDI ®	16.2	146.5 mmol NCO

10

The test specimens (50 g/m² polyurethane PSA on 26 µm polyester film; see above) achieved the following bond strengths:

- 0.72 N/cm on steel,
- 0.81 N/cm on ABS,
- 15 • 0.55 N/cm on PS,
- 0.76 N/cm on PVC.

The tack measurement (on steel) gave a figure of 0.8 N. After two weeks of irradiation with the sunlight lamp there were no changes, either in colour or in bond strength. The adhesion to paper and paperboard was extremely low. The PSA was removable from the

20 substrates simply by shaking. The PSA was stuck into a number of books, newspapers

and magazines. Even after a bonding period of six months, the pages bonded in this way were readily removable from one another and the PSA could be removed readily without leaving residues or greasy spots and without damaging the papers. The PSA did not stick to the skin. Moreover, the PSA was removable by washing. For the purpose of testing it was sprinkled with fine-grained sand and, in a second test, with fine-grained talc. Both substances were easily removable again under running water. Subsequently the bond strength was at the original level. Repeat usability was tested by adhering the PSA to PVC and removing it again 20 times in succession. Thereafter the bond strength was still at the original level.

Example 14

The composition of the inventive polyurethane PSA is as follows:

5

NCO/OH ratio: 1.02

Ratio of number of diol OH/number of triol OH: 2.5

	Ingredient	Weight fraction [% by weight]	Number of OH or NCO groups based on the percentage weight fraction
A component	Desmophen 1262 BD ®	18.0	83.9 mmol OH
	Acclaim 6320 N ®	67.2	33.6 mmol OH
	Bismuth trisneodecanoate	0.3	
	Tinuvin 292 ®	0.3	
	Tinuvin 400 ®	0.6	
	Aerosil R202 ®	1.0	
B component	Vestanat TMDI ®	12.6	119.9 mmol NCO

10

The test specimens (50 g/m² polyurethane PSA on 26 µm polyester film; see above) achieved the following bond strengths:

- 0.32 N/cm on steel,
- 0.31 N/cm on ABS,
- 0.45 N/cm on PS,
- 0.49 N/cm on PVC.

15

The tack measurement (on steel) gave a figure of 0.6 N. After two weeks of irradiation with the sunlight lamp there were no changes, either in colour or in bond strength. The adhesion to paper and paperboard was extremely low. The PSA was removable from the substrates simply by shaking. The PSA was stuck into a number of books, newspapers and magazines. Even after a bonding period of six months, the pages bonded in this way

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were readily removable from one another and the PSA could be removed readily without leaving residues or greasy spots and without damaging the papers. The PSA did not stick to the skin. Moreover, the PSA was removable by washing. For the purpose of testing it was sprinkled with fine-grained sand and, in a second test, with fine-grained talc. Both
5 substances were easily removable again under running water. Subsequently the bond strength was at the original level. Repeat usability was tested by adhering the PSA to PVC and removing it again 20 times in succession. Thereafter the bond strength was still at the original level.

Example 15

The composition of the inventive polyurethane PSA is as follows:

5

NCO/OH ratio: 1.02

Ratio of number of diol OH/number of triol OH: 2.5

	Ingredient	Weight fraction [% by weight]	Number of OH or NCO groups based on the percentage weight fraction
A component	Desmophen 1262 BD ®	16.2	75.6 mmol OH
	Acclaim 6320 N ®	60.6	30.3 mmol OH
	Bismuth trisneodecanoate	0.3	
	Tinuvin 292 ®	0.3	
	Tinuvin 400 ®	0.6	
	Aerosil R202 ®	1.0	
B component	Desmophen N 3300 ®	21.0	108.0 mmol NCO

10

The test specimens (50 g/m² polyurethane PSA on 26 µm polyester film; see above) achieved the following bond strengths:

15

- 0.18 N/cm on steel,
- 0.21 N/cm on ABS,
- 0.31 N/cm on PS,
- 0.26 N/cm on PVC.

20

The tack measurement (on steel) gave a figure of 0.3 N. After two weeks of irradiation with the sunlight lamp there were no changes, either in colour or in bond strength. The adhesion to paper and paperboard was extremely low. The PSA was removable from the substrates simply by shaking. The PSA was stuck into a number of books, newspapers and magazines. Even after a bonding period of six months, the pages bonded in this way

- were readily removable from one another and the PSA could be removed readily without leaving residues or greasy spots and without damaging the papers. The PSA did not stick to the skin. Moreover, the PSA was removable by washing. For the purpose of testing it was sprinkled with fine-grained sand and, in a second test, with fine-grained talc. Both
- 5 substances were easily removable again under running water. Subsequently the bond strength was at the original level. Repeat usability was tested by adhering the PSA to PVC and removing it again 20 times in succession. Thereafter the bond strength was still at the original level.

Example 16

The composition of the inventive polyurethane PSA is as follows:

5

NCO/OH ratio: 1.02

Ratio of number of diol OH/number of triol OH: 2.5

	Ingredient	Weight fraction [% by weight]	Number of OH or NCO groups based on the percentage weight fraction
A component	Desmophen 1262 BD ®	17.5	81.2 mmol OH
	Acclaim 6320 N ®	65.0	32.5 mmol OH
	Bismuth trisneodecanoate	0.3	
	Tinuvin 292 ®	0.3	
	Tinuvin 400 ®	0.6	
	Aerosil R202 ®	1.0	
B component	Desmodur W ®	15.3	116.0 mmol NCO

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The test specimens (50 g/m² polyurethane PSA on 26 µm polyester film; see above) achieved the following bond strengths:

- 0.15 N/cm on steel,
- 0.23 N/cm on ABS,
- 0.18 N/cm on PS,
- 0.21 N/cm on PVC.

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The tack measurement (on steel) gave a figure of 0.3 N. After two weeks of irradiation with the sunlight lamp there were no changes, either in colour or in bond strength. The adhesion to paper and paperboard was extremely low. The PSA was removable from the substrates simply by shaking. The PSA was stuck into a number of books, newspapers and magazines. Even after a bonding period of six months, the pages bonded in this way

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- 5 were readily removable from one another and the PSA could be removed readily without leaving residues or greasy spots and without damaging the papers. The PSA did not stick to the skin. Moreover, the PSA was removable by washing. For the purpose of testing it was sprinkled with fine-grained sand and, in a second test, with fine-grained talc. Both substances were easily removable again under running water. Subsequently the bond strength was at the original level. Repeat usability was tested by adhering the PSA to PVC and removing it again 20 times in succession. Thereafter the bond strength was still at the original level.

Example 17

The composition of the inventive polyurethane PSA is as follows:

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NCO/OH ratio: 1.02

Ratio of number of diol OH/number of triol OH: 2.5

	Ingredient	Weight fraction [% by weight]	Number of OH or NCO groups based on the percentage weight fraction
A component	Desmophen 1112 BD ®	48.7	96.1 mmol OH
	Desmophen 3061 BT ®	34.3	34.3 mmol OH
	Bismuth trisneodecanoate	0.3	
	Tinuvin 292 ®	0.3	
	Tinuvin 400 ®	0.6	
	Aerosil R202 ®	1.0	
B component	Vestanat IPDI ®	14.8	133.1 mmol NCO

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The test specimens (50 g/m² polyurethane PSA on 26 µm polyester film; see above) achieved the following bond strengths:

- 0.21 N/cm on steel,
- 0.31 N/cm on ABS,
- 0.56 N/cm on PS,
- 0.68 N/cm on PVC.

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The tack measurement (on steel) gave a figure of 0.5 N. After two weeks of irradiation with the sunlight lamp there were no changes, either in colour or in bond strength. The adhesion to paper and paperboard was extremely low. The PSA was removable from the substrates simply by shaking. The PSA was stuck into a number of books, newspapers

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and magazines. Even after a bonding period of six months, the pages bonded in this way were readily removable from one another and the PSA could be removed readily without leaving residues or greasy spots and without damaging the papers. The PSA did not stick to the skin. Moreover, the PSA was removable by washing. For the purpose of testing it was sprinkled with fine-grained sand and, in a second test, with fine-grained talc. Both substances were easily removable again under running water. Subsequently the bond strength was at the original level. Repeat usability was tested by adhering the PSA to PVC and removing it again 20 times in succession. Thereafter the bond strength was still at the original level.

Example 18

The composition of the inventive polyurethane PSA is as follows:

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NCO/OH ratio: 1.02

Ratio of number of diol OH/number of triol OH: 4.0

	Ingredient	Weight fraction [% by weight]	Number of OH or NCO groups based on the percentage weight fraction
A component	Desmophen 1112 BD ®	43.1	85.1 mmol OH
	Acclaim 6320 N ®	42.6	21.3 mmol OH
	Bismuth trisneodecanoate	0.3	
	Tinuvin 292 ®	0.3	
	Tinuvin 400 ®	0.6	
	Aerosil R202 ®	1.0	
B component	Vestanat IPDI ®	12.1	108.6 mmol NCO

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The test specimens (50 g/m² polyurethane PSA on 26 µm polyester film; see above) achieved the following bond strengths:

- 0.53 N/cm on steel,
- 0.82 N/cm on ABS,
- 0.93 N/cm on PS,
- 1.12 N/cm on PVC.

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The tack measurement (on steel) gave a figure of 1.1 N. After two weeks of irradiation with the sunlight lamp there were no changes, either in colour or in bond strength. The adhesion to paper and paperboard was extremely low. The PSA was removable from the substrates simply by shaking. The PSA was stuck into a number of books, newspapers and magazines. Even after a bonding period of six months, the pages bonded in this way

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were readily removable from one another and the PSA could be removed readily without leaving residues or greasy spots and without damaging the papers. The PSA did not stick to the skin. Moreover, the PSA was removable by washing. For the purpose of testing it was sprinkled with fine-grained sand and, in a second test, with fine-grained talc. Both substances were easily removable again under running water. Subsequently the bond strength was at the original level. Repeat usability was tested by adhering the PSA to PVC and removing it again 20 times in succession. Thereafter the bond strength was still at the original level.

Example 19

The composition of the inventive polyurethane PSA is as follows:

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NCO/OH ratio: 1.02

Ratio of number of diol OH/number of triol OH: 0.5

	Ingredient	Weight fraction [% by weight]	Number of OH or NCO groups based on the percentage weight fraction
A component	Acclaim 4220 N ®	74.1	37.0 mmol OH
	Desmophen 1380 BT ®	11.1	74.1 mmol OH
	Bismuth trisneodecanoate	0.3	
	Tinuvin 292 ®	0.3	
	Tinuvin 400 ®	0.6	
	Aerosil R202 ®	1.0	
B component	Vestanat IPDI ®	12.6	113.4 mmol NCO

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The test specimens (50 g/m² polyurethane PSA on 26 µm polyester film; see above) achieved the following bond strengths:

- 0.43 N/cm on steel,
- 0.62 N/cm on ABS,
- 0.81 N/cm on PS,
- 0.79 N/cm on PVC.

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The tack measurement (on steel) gave a figure of 0.9 N. After two weeks of irradiation with the sunlight lamp there were no changes, either in colour or in bond strength. The adhesion to paper and paperboard was extremely low. The PSA was removable from the substrates simply by shaking. The PSA was stuck into a number of books, newspapers and magazines. Even after a bonding period of six months, the pages bonded in this way

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were readily removable from one another and the PSA could be removed readily without leaving residues or greasy spots and without damaging the papers. The PSA did not stick to the skin. Moreover, the PSA was removable by washing. For the purpose of testing it was sprinkled with fine-grained sand and, in a second test, with fine-grained talc. Both substances were easily removable again under running water. Subsequently the bond strength was at the original level. Repeat usability was tested by adhering the PSA to PVC and removing it again 20 times in succession. Thereafter the bond strength was still at the original level.

Example 20

The composition of the inventive polyurethane PSA is as follows:

5

NCO/OH ratio: 1.02

Ratio of number of diol OH/number of triol OH: 1.5

	Ingredient	Weight fraction [% by weight]	Number of OH or NCO groups based on the percentage weight fraction
A component	Desmophen 4220 N ®	85.4	42.7 mmol OH
	Desmophen 1380 BT ®	4.3	28.6 mmol OH
	Bismuth trisneodecanoate	0.3	
	Tinuvin 292 ®	0.3	
	Tinuvin 400 ®	0.6	
	Aerosil R202 ®	1.0	
B component	Vestanat IPDI ®	8.1	72.6 mmol NCO

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The test specimens (50 g/m² polyurethane PSA on 26 µm polyester film; see above) achieved the following bond strengths:

- 0.92 N/cm on steel,
- 1.13 N/cm on ABS,
- 1.10 N/cm on PS,
- 0.95 N/cm on PVC.

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The tack measurement (on steel) gave a figure of 1.2 N. After two weeks of irradiation with the sunlight lamp there were no changes, either in colour or in bond strength. The adhesion to paper and paperboard was extremely low. The PSA was removable from the substrates simply by shaking. The PSA was stuck into a number of books, newspapers and magazines. Even after a bonding period of six months, the pages bonded in this way

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were readily removable from one another and the PSA could be removed readily without leaving residues or greasy spots and without damaging the papers. The PSA did not stick to the skin. Moreover, the PSA was removable by washing. For the purpose of testing it was sprinkled with fine-grained sand and, in a second test, with fine-grained talc. Both substances were easily removable again under running water. Subsequently the bond strength was at the original level. Repeat usability was tested by adhering the PSA to PVC and removing it again 20 times in succession. Thereafter the bond strength was still at the original level.

Example 21

The composition of the inventive polyurethane PSA is as follows:

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NCO/OH ratio: 1.02

Ratio of number of diol OH/number of triol OH: 1.5

Ratio of number of diol short-chain OH/number of diol long-chain OH: 1.0

	Ingredient	Weight fraction [% by weight]	Number of OH or NCO groups based on the percentage weight fraction
A component	Desmophen 1262 BD ®	5.6	26.0 mmol OH
	Desmophen 1112 BT ®	13.1	26.0 mmol OH
	Acclaim 6320 N ®	69.3	34.6 mmol OH
	Bismuth trisneodecanoate	0.3	
	Tinuvin 292 ®	0.3	
	Tinuvin 400 ®	0.6	
	Aerosil R202 ®	1.0	
B component	Vestanat IPDI ®	9.8	88.3 mmol NCO

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The test specimens (50 g/m² polyurethane PSA on 26 µm polyester film; see above) achieved the following bond strengths:

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- 0.52 N/cm on steel,
- 0.61 N/cm on ABS,
- 0.92 N/cm on PS,
- 0.83 N/cm on PVC.

The tack measurement (on steel) gave a figure of 0.7 N. After two weeks of irradiation with the sunlight lamp there were no changes, either in colour or in bond strength. The

adhesion to paper and paperboard was extremely low. The PSA was removable from the substrates simply by shaking. The PSA was stuck into a number of books, newspapers and magazines. Even after a bonding period of six months, the pages bonded in this way were readily removable from one another and the PSA could be removed readily without leaving residues or greasy spots and without damaging the papers. The PSA did not stick to the skin. Moreover, the PSA was removable by washing. For the purpose of testing it was sprinkled with fine-grained sand and, in a second test, with fine-grained talc. Both substances were easily removable again under running water. Subsequently the bond strength was at the original level. Repeat usability was tested by adhering the PSA to PVC and removing it again 20 times in succession. Thereafter the bond strength was still at the original level.

Example 22

The composition of the inventive polyurethane PSA is as follows:

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NCO/OH ratio: 1.02

Ratio of number of diol OH/number of triol OH: 1.5

Ratio of number of triol short-chain OH/number of triol long-chain OH: 2.0

	Ingredient	Weight fraction [% by weight]	Number of OH or NCO groups based on the percentage weight fraction
A component	Desmophen 1262 BD ®	16.3	75.7 mmol OH
	Desmophen 3061 BT ®	33.6	33.6 mmol OH
	Acclaim 6320 N ®	33.6	16.8 mmol OH
	Bismuth trisneodecanoate	0.3	
	Tinuvin 292 ®	0.3	
	Tinuvin 400 ®	0.6	
	Aerosil R202 ®	1.0	
B component	Vestanat IPDI ®	14.3	128.7 mmol NCO

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The test specimens (50 g/m² polyurethane PSA on 26 µm polyester film; see above) achieved the following bond strengths:

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- 0.30 N/cm on steel,
- 0.41 N/cm on ABS,
- 0.32 N/cm on PS,
- 0.27 N/cm on PVC.

The tack measurement (on steel) gave a figure of 0.3 N. After two weeks of irradiation with the sunlight lamp there were no changes, either in colour or in bond strength. The

adhesion to paper and paperboard was extremely low. The PSA was removable from the substrates simply by shaking. The PSA was stuck into a number of books, newspapers and magazines. Even after a bonding period of six months, the pages bonded in this way were readily removable from one another and the PSA could be removed readily without leaving residues or greasy spots and without damaging the papers. The PSA did not stick to the skin. Moreover, the PSA was removable by washing. For the purpose of testing it was sprinkled with fine-grained sand and, in a second test, with fine-grained talc. Both substances were easily removable again under running water. Subsequently the bond strength was at the original level. Repeat usability was tested by adhering the PSA to PVC and removing it again 20 times in succession. Thereafter the bond strength was still at the original level.

Example 23

The composition of the inventive polyurethane PSA is as follows:

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NCO/OH ratio: 1.02

Ratio of number of diol OH/number of triol OH: 1.0

Ratio of number of NCO (IPDI)/NCO (TMDI): 2.0

	Ingredient	Weight fraction [% by weight]	Number of OH or NCO groups based on the percentage weight fraction
A component	Desmophen1262 BD ®	8.6	40.1 mmol OH
	Acclaim 6320 N ®	80.2	40.1 mmol OH
	Bismuth trisneodecanoate	0.3	
	Tinuvin 292 ®	0.3	
	Tinuvin 400 ®	0.6	
	Aerosil R202 ®	1.0	
B component	Vestanat IPDI ®	6.1	54.6 mmol NCO
	Vestanat TMDI	2.9	27.3 mmol NCO

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The test specimens (50 g/m² polyurethane PSA on 26 µm polyester film; see above) achieved the following bond strengths:

- 0.14 N/cm on steel,
- 0.27 N/cm on ABS,
- 0.39 N/cm on PS,
- 0.48 N/cm on PVC.

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The tack measurement (on steel) gave a figure of 0.4 N. After two weeks of irradiation with the sunlight lamp there were no changes, either in colour or in bond strength. The adhesion to paper and paperboard was extremely low. The PSA was removable from the

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substrates simply by shaking. The PSA was stuck into a number of books, newspapers and magazines. Even after a bonding period of six months, the pages bonded in this way were readily removable from one another and the PSA could be removed readily without leaving residues or greasy spots and without damaging the papers. The PSA did not stick to the skin. Moreover, the PSA was removable by washing. For the purpose of testing it was sprinkled with fine-grained sand and, in a second test, with fine-grained talc. Both substances were easily removable again under running water. Subsequently the bond strength was at the original level. Repeat usability was tested by adhering the PSA to PVC and removing it again 20 times in succession. Thereafter the bond strength was still at the original level.

Comparative examples

Comparative Example 1

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Polyurethane composition:

NCO/OH ratio: 0.95

Ratio of number of diol OH/number of triol OH: 5.0

	Ingredient	Weight fraction [% by weight]	Number of OH or NCO groups based on the percentage weight fraction
A component	Desmophen 1262 BD ®	31.8	148 mmol OH
	Desmophen 5035 BT ®	47.3	29.5 mmol OH
	Mark DBTL ®	0.3	
	Tinuvin 292 ®	0.3	
	Tinuvin 400 ®	0.6	
	Aerosil R202 ®	1.0	
B component	Vestanat IPDI ®	18.7	168.6 mmol NCO

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The test specimens (50 g/m² polyurethane PSA on 26 µm polyester film, see above) achieved a bond strength on steel of 7.4 N/cm. The PSA bonded very strongly to paper, and so could by no means be removed from the paper simply by shaking. It likewise

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bonded very strongly to the skin.

Comparative Example 2

Polyurethane composition:

5 NCO/OH ratio: 0.7

Ratio of number of diol OH/number of triol OH: 2.5

	Ingredient	Weight fraction [% by weight]	Number of OH or NCO groups based on the percentage weight fraction
A component	Desmophen 1262 BD ®	21.7	101.3 mmol OH
	Desmophen 5035 BT ®	65.0	40.5 mmol OH
	Bismuth trisneodecanoate	0.3	
	Tinuvin 292 ®	0.3	
	Tinuvin 400 ®	0.6	
	Aerosil R202 ®	1.0	
B component	Vestanat IPDI ®	11.1	99.3 mmol NCO

- 10 The test specimens (50 g/m² polyurethane PSA on 26 µm polyester film, see above) achieved a bond strength on steel of 8.2 N/cm. The PSA bonded very strongly to paper, and so could by no means be removed from the paper simply by shaking. In addition it left spots of greasy appearance on the paper after just a short time. It additionally bonded very strongly to the skin.

Comparative Example 3

Polyurethane composition:

5 NCO/OH ratio: 1.02

Ratio of number of diol OH/number of triol OH: 1.0

	Ingredient	Weight fraction [% by weight]	Number of OH or NCO groups based on the percentage weight fraction
A component	Desmophen 1262 BD ®	35.6	166.0 mmol OH
	Desmophen 1380 BT ®	24.6	166.0 mmol OH
	Bismuth trisneodecanoate	0.3	
	Tinuvin 292 ®	0.3	
	Tinuvin 400 ®	0.6	
	Aerosil R202 ®	1.0	
B component	Vestanat IPDI ®	37.6	338.6 mmol NCO

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The test specimens (50 g/m² polyurethane PSA on 26 µm polyester film, see above) achieved a bond strength on steel and on plastics of less than 0.1 N/cm. The bond strength was too low to fix lightweight plastic parts.